

**DEVELOPMENT OF A DOD HANDBOOK ON
INSPECTION AND TESTING OF LIGHTNING PROTECTION
AND GROUNDING SYSTEMS**

presented by

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ABSTRACT

There is currently little standardization in the instrumentation of ground system testing and visual inspection requirements in the Department of Defense. As result, the Department of Defense Explosives Safety Board (DDESB) has tasked the Naval Surface Warfare Center to develop a handbook that will provide recommendations on the development of a grounding system quality control program and provide general discussions on conducting visual inspections and electrical testing. This paper provides a general discussion on the proposed content of the handbook with emphasis on the development of a grounding system quality control program and on the results of a survey on the implementation of current grounding system test requirements in the field. The paper will forward any preliminary recommendations proposed for inclusion on the handbook.

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DEVELOPMENT OF A DOD HANDBOOK ON INSPECTION AND TESTING OF LIGHTNING PROTECTION AND GROUNDING SYSTEMS

1.0 Introduction

There is currently little standardization in the grounding system test and inspection procedures used at Department of Defense (DOD) ordnance facilities. As a result, the Department of Defense Explosives Safety Board (DDESB) has tasked the Naval Surface Warfare Center (NAVSWC) to develop a handbook which will provide recommendations on the development of a grounding system quality control program and provide discussions on conducting visual inspections and electrical testing of grounding systems for ordnance facilities. The Defense Nuclear Agency (DNA) suggested that the goal should also be to produce a publication that will permit those personnel responsible for inspection and maintenance of these systems to readily understand both the how and why of pertinent requirements [1]. It was suggested that the document contain guidance that will be easy to understand with clear definitions of what is satisfactory and what is unsatisfactory. Check sheets and general test procedures should be provided.

It is agreed that the general opinion of personnel in the field responsible for the design, installation, maintenance, and inspection of grounding systems for ordnance facilities is that specific visual inspection and electrical test procedures should be used for all DOD ordnance facilities. However, the existing service requirements for grounding systems testing [2][3][4][5] are very general as to the specific items that are to be tested and the test procedures to be used. Implementing documents for the services could be interpreted to be in conflict as to specific details of implementation. For example, Air Force Pamphlet 91-38 [6] allows that the reference electrodes for a three-point fall-of-potential earth resistance test be installed in such a way that the potential electrode is one-half of the diagonal distance of the building, but not less than 25 feet. The current electrode is to be placed 90 degrees from the potential electrode and the "item under test", at the same distance as the potential electrode. NAVSEA OP-5 [3], Chapter 4-9.2.5 requires that these tests be conducted "in accordance with the appropriate instrument manufacturer's instructions". It also references James G. Biddle Company's Manual 25T [7] on earth resistance testing which requires that the current and potential electrodes be in a straight line and that the spacing of the electrodes must be determined by some baseline testing of the installed grounding systems. In order to establish a specific test procedure, the services must agree on the resolution of those areas where there can be perceived to be conflicts between the

implementing documents of the services. DOD 6055.9-STD [2] only provides general guidance in those areas where potential conflicts exist. In addition, there is a very broad spectrum of age, construction, and end use of facilities currently being utilized by DOD agencies.

Kilkeary, Scott and Associates, Inc. (KSAi) has been tasked to support NAVSWC in the production of this handbook. As a part of this task, KSAi has reviewed several DOD documents dealing with grounding systems installation and testing requirements for ordnance facilities [2][3][4][5][6][8][9][10] and other literature on the subject [11][12][13][14]. This paper reports on the recommendations of KSAi on inspection and testing techniques proposed for the handbook.

2.0 BACKGROUND

DOD 6055.9-STD [2], NAVSEA OP-5 [3], AFR 127-100 [4], and AMCR 385-100 [5] provide requirements for the installation of lightning protection and grounding systems for DOD ordnance facilities. DOD 6055.9-STD [2] does not require a counterpoise for a lightning protection system if the resistance-to-ground is less than 10 ohms. Army [5] and Air Force [4] regulations are identical to the DOD [2] requirement. However, NAVSEA OP-5 [3], 4-9.2.3 requires that 1/0 AWG cable form a closed loop around the area to be protected to electrically interconnect lightning protection system down conductors, regardless of resistance-to-earth. In addition, Navy requirements do not allow the use of an integral lightning protection system for ordnance facilities even though all other services [2][4][5] will accept mast-type, overhead wire, and "Faraday-type" lightning protection systems. Figure (1), taken from AMCR 385-100 [5], provides a detail of a typical integral lightning protection system installation for an Army or Air Force application. Figure (2), taken from NAVSEA OP-5 [3], provides a detail of a typical Navy mast-type lightning protection and grounding system installation.

A primary difference between the internal grounding requirements of the various services is the Navy use of an "ordnance grounding system". NAVSEA OP-5 [3], 4-7.1.5 requires that the ordnance grounding system be installed as a single-point grounding system, isolated from all other grounding systems except through direct attachment to a buried (secondary) ground girdle (see Figure (2)). All of the DOD requirements reviewed required the bonding of metallic bodies in the facilities as part of the lightning protection system. Surge suppression for all incoming metallic conductors is also required by all of the requirements documents. They all also require that fences have bonds across

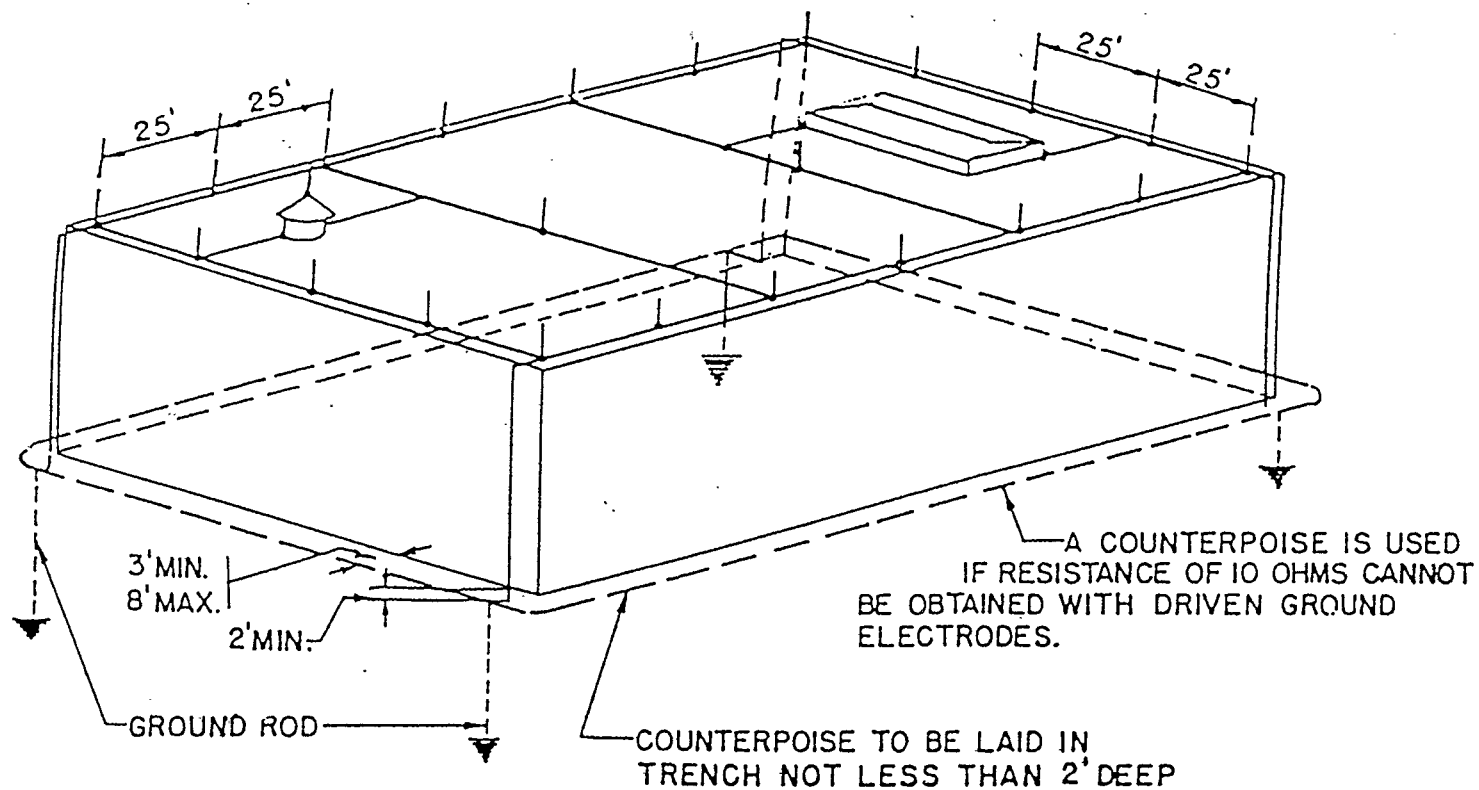
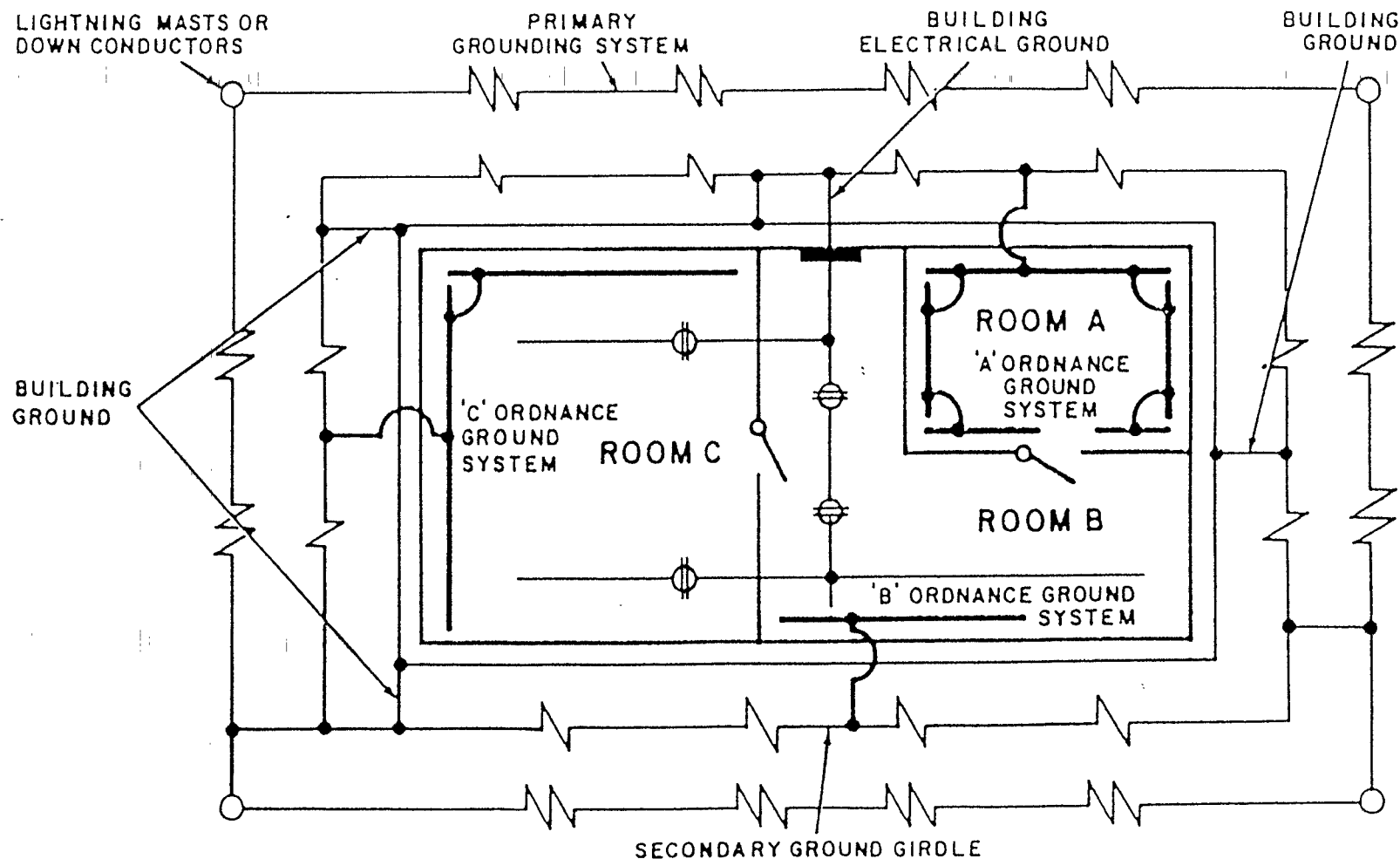


Figure 1. Typical Integral Lightning Protection System Installation



NOTE

PRIMARY AND SECONDARY GIRDLES
SHALL BE INTERCONNECTED

Figure 2. Typical Navy Mast-Type Lightning Protection and Grounding System

gates. DOD 6055.9-STD [2] requires that fences and railroad tracks be bonded to the lightning protection grounding system if they come within six (6) feet of the structure. DOD 6055.9-STD also requires that wires and connectors on lightning protection systems not be painted.

DOD requirements [2] specify that the lightning protection systems shall be inspected visually every seven (7) months and tested electrically every fourteen (14) months. DOD [2] and Navy [3] requirements specify that the testing be conducted in accordance with the appropriate instrument manufacturer's instructions by personnel familiar with lightning protection systems. NAVSEA OP-5 [3], 4-9.2.5 requires that the resistance of each mast and overhead lightning conductor to earth shall be measured every 14 months. It also requires that the resistance-to-ground of all metal objects that require interconnection with the lightning protection system be measured and recorded. The resistance between these components and the lightning protection system shall be less than one (1) ohm.

Army [5] and Air Force [6] documents provide specific lightning protection and grounding systems test procedures. AFP 91-38 [6], 2-3 states that the electrical test procedures forwarded in the document is the "correct procedure for testing typical" Air Force systems. The resistance-to-ground test method discussed in AFP 91-38 [6] utilizes reference electrodes spaced at 90 degrees to the edge of the building. The distance between electrodes is to be one-half of the diagonal distance of the building, but not less than 25 feet. The inference from the Navy requirements [3] would require that the reference electrodes be in a straight line at a distance determined by some baseline testing. AFR 127-100 [4] and AMCR 385-100 [5] also requires a continuity test for masts or overhead wire lightning protection systems from the top of the mast or overhead wire to the ground point connection. No such test requirements are included in NAVSEA OP-5 [3]. Both the Army [5] and the Air Force [4] requires continuity measurements between air terminals and ground electrodes for integral lightning protection systems. Navy documents [3] do not address the testing of integral lightning protection systems.

All of the DOD documents reviewed [2][3][4][5][6] require that the test instruments used in the testing of DOD lightning protection systems be capable of ten (10) percent accuracy at one (1) ohm for bonding measurements and ten (10) ohms for resistance-to-ground measurements. Only instruments designed for the testing of earth resistance may be used in resistance-to-ground testing.

NFPA 78 [12], Appendix M-4 recommends an annual visual inspection and a thorough inspection every five (5) years. The inspection requirements in NFPA 78 [12] Appendix L-7 are identical to those in DOD 6055.9-STD [2], paragraph F. NFPA 78 [12],

Appendix B recommends the use of checklists for routine maintenance to enhance the repeatability of the procedures used in the inspections. The Appendix recommends that the maintenance program should contain provisions for: (1) the inspection of all conductors and systems components, (2) tightening of all clamps and splicers, (3) measurement of system resistance, (4) measurement of the earth resistance of the ground terminals, (5) inspection and/or testing of surge suppression devices, and (6) inspection and testing to ensure that the effectiveness of the lightning protection system has not been altered as a result of additions to or changes in the structure.

3.0 GROUNDING SYSTEMS TEST PLAN

KSai recommends that the proposed DOD handbook encourage each facility to establish a grounding systems test plan for the facility. This grounding systems test plan should detail the responsibility for the overall implementation of the plan and should also detail the responsibilities delegated to other offices. Specifically, the grounding system test plan should identify the procedure by which grounding systems test points will be selected, the procedure to be used in the visual inspection of lightning protection and grounding systems, the responsibility for the development of specific electrical test procedures, the responsibility for the review of electrical test data and the initiation of corrective action, the procedure by which priorities for corrective action are to be established, and the responsibility for ensuring that any necessary modification are made. It is also recommended that the grounding system test plan identify specific procedures by which it will be ensured that the test procedures for a facility is upgraded any time the operations or structural configuration of the facility is changed. Finally, training requirements and personnel qualifications for each level of responsibility should be included in the grounding system test plan.

None of the services require such a grounding system test plan for a facility. However, all of the services require that the electrical testing and visual inspections be conducted and that records of the electrical testing be maintained for a minimum of five (5) years. The grounding system test plan is suggested as a technique to ensure that the maintenance and inspection requirements of the Department of Defense are met and the procedures used to implement the plan are clearly documented and can be easily inspected to ensure maximum grounding system effectiveness.

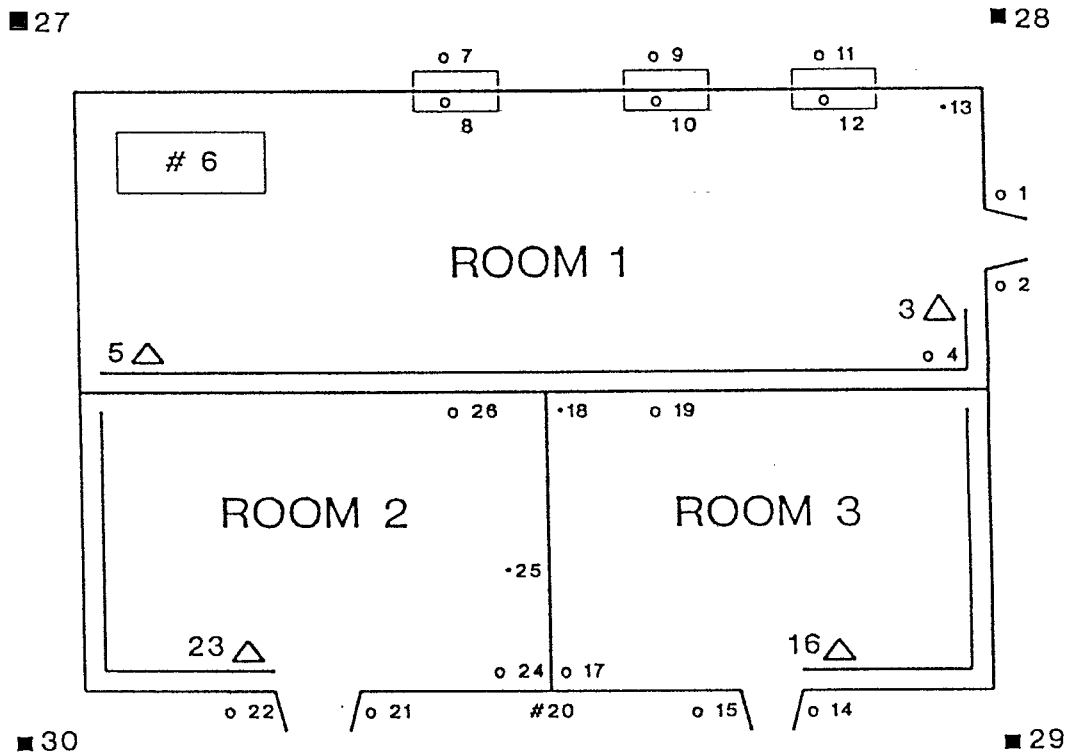
It is recommended that a visual inspection checklist be provided in the grounding system test plan. None of the requirements documents reviewed [2][3][4][5] specifically address a visual inspection checklist. However, each of the documents provide suggestions on the items to be reviewed during visual inspections. Section 4.0 of this report provides recommendations on visual inspection checklists.

It is recommended that the grounding system test plan discussed in the proposed handbook encourage the use of a sketch of the grounding system for a structure to identify the test point location and type of measurement required for each test point. An example of such a sketch for a Navy structure is provided in Figure (3). In the example provided, the types of grounding systems are identified by symbol on the sketch and are listed below the sketch to ensure no confusion. A proposed electrical test record form indicating the type of test required is provided as Figure (4). It is recommended that the electrical test results recorded in the field be transferred to a computer data file where they can be reviewed and maintained for the life of the structure. The effectiveness of a trend analysis is enhanced when several seasons of test data is available.

If the resistance-to-ground of individual ground rods for lightning protection and grounding systems is to be measured in order to compute the earth resistance of a buried ground ring, it is necessary that the grounding system test plan identify that the ground rods (and perhaps grounding girdles) be provided with test pockets to allow their disconnection from the ground girdle. Subsequent designs of grounding systems at the facility should include such test pockets. For Navy installations, ordnance grounding systems should be installed in such a manner to allow that it be disconnected (to test for isolation) and then reconnected (to ensure proper bonding to the secondary grounding system). Such a design should be implemented at Navy and Marine Corp installations whenever isolation testing of the ordnance grounding systems is included in the grounding systems test plan.

4.0 VISUAL INSPECTION PROCEDURES

NFPA 78 [12], Appendix B-1.2 recommends that the visual inspections include checks to ensure the system is in good repair, there are no loose connections (or paint on the joints) that might result in high resistance connections, the system has not been weakened by corrosion or vibration, all conductors are securely fastened, there has been no additions or alterations to the structure that would require additional protection, and that there has been no visual indication of damage to surge suppression devices. KSAi also suggests that ground fault interrupters (GFI)



- | | |
|-------------------------|--------------------------|
| 1 = Door | 16 = Ordnance ground bus |
| 2 = Door | 17 = Structure |
| 3 = Ordnance ground bus | 18 = Conduit |
| 4 = Structure | 19 = Missile stand |
| 5 = Ordnance ground bus | 20 = Ground grab bar |
| 6 = Metal table top | 21 = Door |
| 7 = Window guard | 22 = Door |
| 8 = Window | 23 = Ordnance ground bus |
| 9 = Window guard | 24 = Structure |
| 10 = Window | 25 = Conduit |
| 11 = Window guard | 26 = Structure |
| 12 = Window | 27 = Mast |
| 13 = Conduit | 28 = Mast |
| 14 = Door | 29 = Mast |
| 15 = Door | 30 = Mast |

Figure 3. Sketch of a Navy Ordnance Facility showing Electrical Test Points

BUILDING KSAi

3-Point Fall-of-Potential (10 ohms maximum)

Test Point	Resistance (ohms)	Test Point	Resistance (ohms)
1		30	
20		28	

Bonding Measurements (1 ohm maximum)

Test Point	To	Test Point	Resistance (ohms)	Comments
1		28		
20		30		
30		29		
30		27		
1		20		
1		2		
1		5		
1		4		
1		6		
1		7		
1		8		
1		9		
1		10		
1		11		
1		12		
1		13		
20		14		
20		15		
20		16		
20		17		
20		18		
20		19		
20		21		
20		22		
20		23		
20		24		
20		25		
20		26		

Figure 4. Proposed Data Sheet for Example Structure

also be checked (where practical) as a part of the visual inspection. KSAi suggests that Navy inspections also include a check of all ordnance grounding systems to ensure that they are independently bonded to the secondary ground girdle. It is also recommended that a copy of the previous electrical test data be reviewed prior to the visual inspection and that any unusual test points be examined in detail during the inspection.

The use of checklists in visual inspections is recommended. Lt. Colonel (USAF) Mercer, Defense Nuclear Agency representative to the DOD Lightning Protection and Equipment Grounding Requirements Working Group (LPEGRWG), presented a Lightning Protection System Inspection Guide [15] for review by the LPEGRWG. The guide was developed by DNA Field Command for use by their inspection teams. The guide was arranged along the lines of a checklist, asking questions and providing references of applicable requirements documents. KSAi supports the use of such a checklist for conducting visual inspections to aid the inspection personnel in assuring that all of the critical items have been tested and to ensure repeatability of the visual inspections. KSAi is aware of some Navy facilities that are currently in the process of developing their own checklist for visual inspections of grounding and lightning protection systems. The checklists proposed are similar in design to the DNA checklist, although only Navy documents are referenced. It is recommended that the handbook provide an outline for a suggested checklist, but each individual facility should have the freedom to tailor their checklist to best meet the applications specific to the station.

5.0 ELECTRICAL TESTING

KSAi is aware of a large variation in ground system test techniques used at DOD facilities. Some activities have reported that they conduct point-to-point resistance testing between the item under test and a reference point, some conduct 3-point fall-of-potential testing (with different electrode location requirements between services), and some use a combination of the tests.

The Navy [3] requires that 3-point fall-of-potential resistance-to-ground testing be conducted for all lightning protection masts or overhead wires and for all metallic objects requiring bonding to the secondary grounding system. However, in areas of constant soil resistivity it is possible that independently grounded objects could yield a very similar resistance-to-ground. KSAi feels that it is most important that the bonding resistance between the metallic components be measured to ensure there are no independently grounded objects.

As discussed in Section 2.0, there is a good deal of difference in the resistance-to-earth measurement techniques used by the services. AFP 91-38 [6] requires the test procedure summarized in Figure (5) while NAVSEA OP-5 [3] can be interpreted to require that the electrodes be installed in a straight line, as shown in Figure (6) (taken from Biddle Instruments "Getting Down to Earth"[7]). Biddle Instruments [7] suggests that the electrode spacing "D" be such that the electrodes are located outside of the "sphere of influence" of the electrode under test. Biddle suggests a series of tests to determine which electrode configurations will be required for a particular installation.

Metallic items in the ground or inconsistencies in soil resistivities can influence the validity of resistance-to-earth measurements. The principle of a 3-point fall-of-potential grounding resistance test is to inject a constant current into the ground via the C2 electrode and measure the potential between the P2 electrode and the item-under-test (see Figure (6)). Any conductor in the ground such as metal water pipe or conduit can influence the current path in the ground and therefore cause errors in the values measured.

In addition, the Navy [3] specifies that a resistance-to-ground of 10 ohms or less is acceptable. However, Figure (7) provides an example of typical resistance-to-ground test data for a DOD magazine. A review of the data shows that the air terminal and the vent consistently exhibit a higher earth resistance than the other test points, even though none of the values recorded are greater than 10 ohms. However, the large difference in resistance-to-ground values is an indication that the air terminal and vent are not bonded to the other grounds in the structure. It is recommended that the handbook provide recommendations on the review of electrical test data. Some discussion should be provided on the development of ground system test procedures that will provide the data required for proper analysis.

It is recommended that the handbook propose the use of both resistance-to-ground and point-to-point bonding resistance measurements. The handbook should stress the importance of bonding measurements and should provide guidance on the selection of test points. It is recommended that the handbook stress the use of electrical test data sheets with test point locations clearly labeled on the data sheet or a supporting sketch of the facility. It is recommended that the DOD Lightning Protection and Equipment Grounding Requirements Working Group address the specific 3-point fall-of-potential test methods that should be included in the handbook.

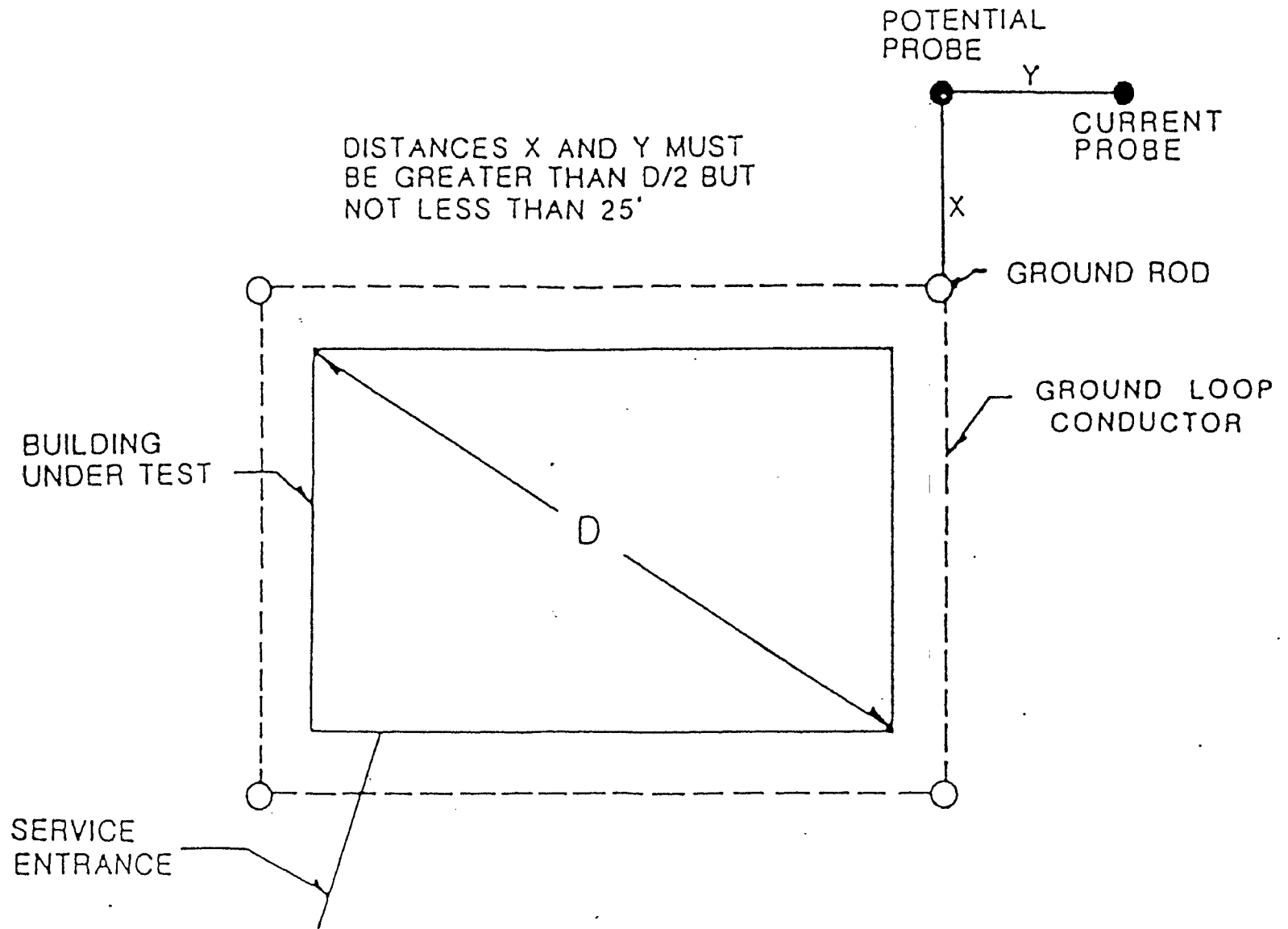


Figure 5. Electrode Locations for Air Force Fall-of-Potential Ground Resistance Test

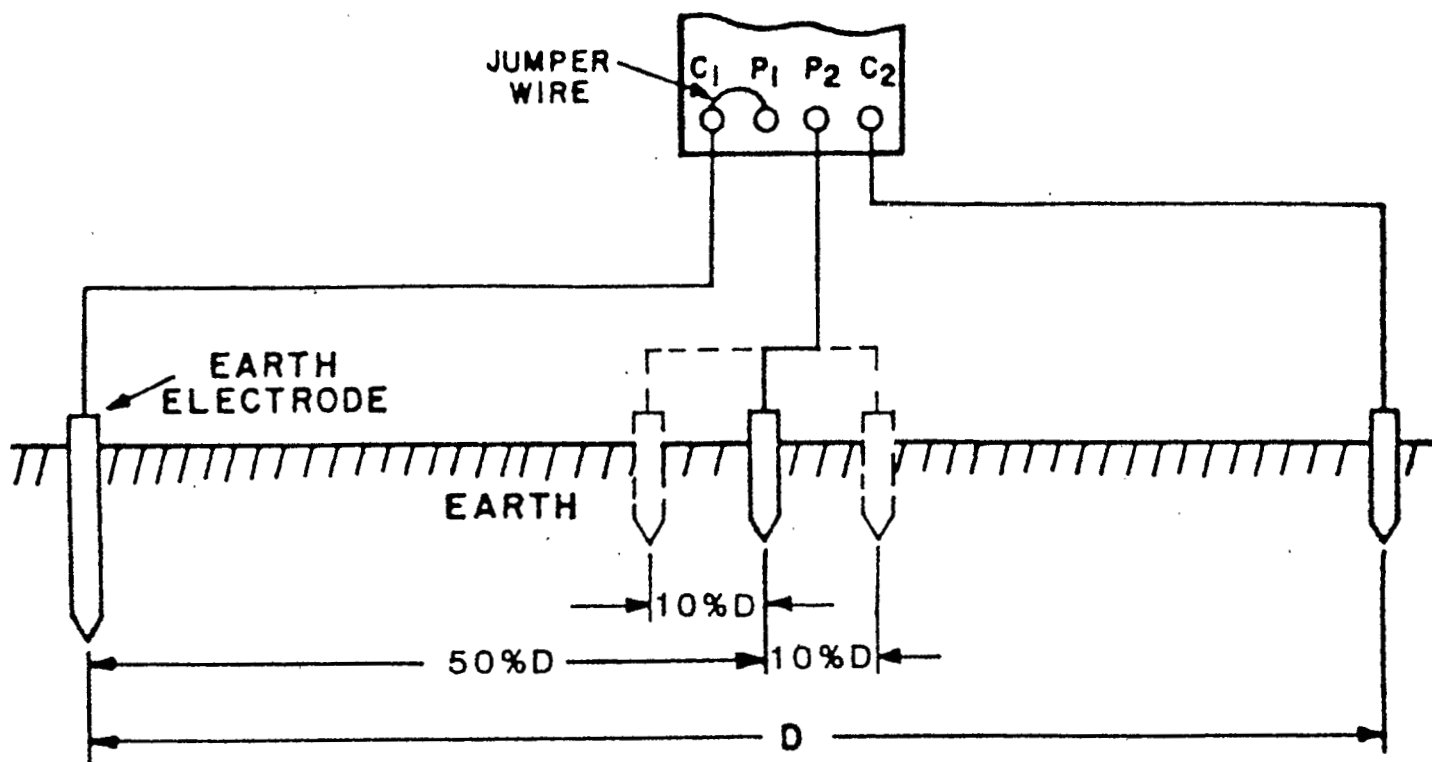


Figure 6. Biddle Instruments Recommended Electrode Configuration for Fall-of-Potential Ground Resistance Test

BUILDING 9AX3

Test Point	Location	Date			
		5/9/86	4/7/87	7/18/88	10/27/89
1	Door	3.0	2.6	3.6	3.0
2	Inside Gnd	3.0	2.6	3.2	3.1
3	Inside Gnd	2.8	2.6	3.4	3.1
4	Inside Gnd	2.8	2.6	3.2	3.1
5	Inside Gnd	2.8	2.6	3.2	3.0
6	Door	3.0	2.6	3.2	3.0
7	Air Terminal	6.5	6.0	7.0	6.5
8	Vent	6.3	6.2	6.9	6.5

Figure 7. Earth Resistance Test Data for DoD Magazine

6.0 SUMMARY

In summary, the Department of Defense Explosives Safety Board has tasked the Naval Surface Warfare Center to develop a handbook on conducting visual inspections and electrical testing of DOD ordnance facility grounding systems. It is the intent of this action to promote some standardization in the implementation of grounding system inspection and testing requirements. It has been recommended that the handbook provide clear guidance as to correct and incorrect installations and that specific electrical test procedures and checklists be provided. However, the requirements being implemented in the field are very general and sometimes one service's implementation of a requirement is very different from another service. In order to provide specific guidance for conducting visual inspections and provide specific electrical test procedures, the services must first agree to a single test procedure. It is recommended that the DOD Lightning Protection and Equipment Requirements Grounding Working Group provide the forum for the resolution of such issues.

It is recommended that the handbook encourage the development of grounding systems test plans for DOD ordnance facilities. The grounding system test plan should detail the responsibilities for each phase of the implementation of the plan, should identify the key items to be checked during visual inspections, should provide guidance for the selection of test points in electrical testing, should identify personnel responsible for conducting visual inspections and electrical testing, should provide specific grounding system test procedures, should identify personnel responsible for the review of the test data, identify how work requests are to be processed should any repairs be required, and detail the procedure to be used in assigning priorities to the work requests. Electrical testing Standard Operating Procedures (SOPs) should be developed and included in the test plan, along with any visual inspection checklists. If specific sketches of the ordnance facilities are developed (see Figure (3)), these too should be included in the grounding system test plan. In summary, the grounding system test plan should contain a complete summary of all elements of grounding systems inspection and testing at a DOD facility.

It is recommended that a visual inspection checklist be established for inclusion in the handbook. It may be necessary to develop a different checklist for each service. The checklist should list all items to be inspected and provide some pass/fail criteria for the inspection. It should also provide references for each requirement.

It is recommended that both point-to-point bonding resistance and three-point fall-of-potential earth resistance testing is discussed in the handbook. Specific details for the procedures used in conducting both types of tests should be included in the handbook. It is recommended that the handbook stress the importance of bonding resistance testing and provide some discussion on the limitations of earth resistance testing.

In conclusion, the handbook must be written so that it is easily understood and contain guidance that is directive in nature. Detailed test procedures and inspection guidelines should be provided for maximum usefulness of the document. In practice, such a combination may not be practical without each of the services agreeing on specific procedures that are to be included in the handbook.

BIBLIOGRAPHY

- [1] Defense Nuclear Agency letter LEEE of 8 May 1989.
- [2] DOD 6055.9-STD, "Ammunition and Explosives Safety Standards", Department of Defense Explosives Safety Board, Washington, DC, July 1984.
- [3] NAVSEA OP-5, "Ammunition and Explosives Ashore", Volume 1, Fourth Revision, Change 15, Naval Sea Systems Command, Washington, DC, 15 February 1988.
- [4] AFR 127-100, "Explosives Safety Standards", Headquarters US Air Force, Washington, DC, May 1983.
- [5] AMCR 385-100, "Safety Manual", Army Material Command, Alexandria, VA, 1985.
- [6] AFP 91-38, "Maintenance of Electrical Grounding Systems", Headquarters US Air Force, Washington, DC, 2 October 1989.
- [7] Getting Down to Earth, Fourth Revision, Biddle Instruments, Blue Bell, PA, April 1981.
- [8] MIL-HDBK-1004/6, "Military Handbook, Lightning Protection", Naval Facilities Engineering Command, Washington, DC, 30 May 1988.
- [9] Army TM 5-811-3, Air Force AFM 88-9, Chapter 3, "Electrical Design, Lightning and Static Electricity Protection", Departments of the Army and the Air Force, Washington, DC, 28 August 1988.
- [10] MIL-HDBK-419, "Grounding, Bonding, and Shielding for Electronic Equipments and Facilities", Volumes I and II, Department of Defense, Washington, DC, 21 January 1982.
- [11] NFPA 70, "National Electrical Code", National Fire Protection Association, Quincy, MA, 1989.
- [12] NFPA 78, "Lightning Protection Code", National Fire Protection Association, Quincy, MA, 1989.
- [13] Sarajoa, E. K., "18. Lightning Earths", Lightning, Volume 2, edited by Dr. R. H. Golde, Academic Press, London, 1977.
- [14] Moore, C. B., M. Brook, and E. P. Krider, A Study of Lightning Protection Systems, prepared for Atmospheric Science Program of The Office of Naval Research, Arlington, VA, October 1981.
- [15] Defense Nuclear Agency Field Command, "Lightning Protection System (LPS) Inspection Guide", Kirtland Air Force Base, NM, presented to DOD Lightning Protection and Equipment Grounding Requirements Working Group.